



The Effect of Active Paper Packaging Enriched with Oleoresin from Solid Waste of Pressed *Curcuma xanthorrhiza* Roxb. Placement Methods on Quality of Refrigerated Strawberry (*Fragaria x ananassa*)

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Abstract

Strawberry is a popular and nutritious fruit. However, its improper post-harvest handling leads to quality degradation. The aim of this study was to investigate the effects of active paper packaging placements methods on strawberry (*Fragaria x ananassa*) quality during refrigerated storage. Strawberry quality was determined based on the physical (weight loss, hardness, color), chemical (pH, total titratable acid, total soluble solids and vitamin C content) and microbiological (total plate count) properties. The results of this study indicated that different placement methods of active paper packaging had no significant effect on the physical and chemical qualities; but it did affect the microbiological quality of the strawberries. At the end of the experiment (12 days), the microbial content of C (the bottom and walls), D (covering all surfaces) and E (cut into pieces) samples were significantly lower than the A (without active paper packaging) and B (the bottom) samples. The Total Plate Count (TPC) values of the control and B samples were higher than the maximum acceptable limit of 6 log₁₀ colony-forming units (CFU) g⁻¹, while the other samples remained below the limit. These results indicated that a larger surface area of active paper that had contact with the strawberries provided better protection against microbes. Due to their microbial properties, C, D and E treatments maintained the strawberry quality for up to 12 days, compared with 9 days for control and B treatments. Active paper packaging containing oleoresin from solid waste of pressed *Curcuma xanthorrhiza* Roxb. can be applied to extend the shelf life of strawberries during refrigerated storage.

Keywords: active paper packaging; *Curcuma xanthorrhiza* Roxb.; food quality; refrigerated storage; strawberry

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INTRODUCTION

Strawberry (*Fragaria x ananassa*) is a popular fruit commodity in subtropical regions and tropical regions such as Indonesia. Strawberry production continues to increase in response to increased demand. Globally, the production of strawberry gradually increased from 8,069,134

tons in 2017 to 8,337,099 tons in 2018 (FAO, 2020). In Indonesia, during 2014-2019 the production of strawberry varied from 7,501 tons to 58,884 tons (BPS - Statistics Indonesia, 2020). Strawberry fruit is a horticultural commodity with high nutritional value. According to USDA (2017), strawberry has a fairly complete nutritional content, with each berry containing up

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to 32 calories, 0.67 g of protein, 0.30 g of fat, 7.68 g of carbohydrate, 2.0 g of fiber, 16 mg of calcium, 24 mg of phosphorus, 153 mg of potassium, 12 IU of vitamin A, 0.024 mg of vitamin B1, 58.8 mg of vitamin C and 90.95 g of water. Strawberry also shows strong antioxidant capacity related to its phenolic compounds and flavonoids content (Skrovankova et al., 2015).

Improper post-harvest handling of strawberry leads to quality degradation, including poor appearance, weight loss and decreased nutritional value. During storage, strawberries are susceptible to microbial damage which is caused by mold and bacteria. Pathogenic molds infecting strawberries include *Botrytis cinerea*, which causes gray patches, *Colletotrichum acutatum*, which causes anthracnose fouling and *Phytophthora cactorum*, which causes rotting of the fruit skin. Bacteria which cause soft rot in strawberries include *Erwinia carotovora*, *Pseudomonas marginalis* and species from the genus *Weeksella* (Yuliasari et al., 2015). Strawberry damage in the form of soft and watery rotting with brown stains is caused by *Rhizopus stolonifer* and *Mucor piriformis* (Siefkes-Boer et al., 2009). These conditions could increase the post-harvest losses due to deterioration, loss of quality, loss of nutritional value, loss of viability and finally commercial loss (Sawicka, 2019). Therefore, the reduction of postharvest losses may become a central pillar of sustainable global food systems (Kikulwe et al., 2018).

Post-harvest losses of strawberry during storage can be inhibited by proper packaging. Packaging can also improve the appearance of the product and prevent products from contaminations (Qanytah and Ambarsari, 2011). Strawberries are usually packaged in mica polyethylene (PET) punnets coated with paper at the bottom side of the packaging. The purpose of the paper is to prevent friction between the fruits and its packaging and ensure that physical damage is minimized. Additional antimicrobial compounds can be added to the paper to improve the functionality of the paper packaging. This active packaging actively changes the condition of the packaged food, prolongs the product's shelflife, enhances the safety of food and maintain food taste and quality (Rodríguez et al., 2008).

Spices and their components, such as oleoresin and essential oils, are commonly used as additive compounds on active packaging. Brody et al.

(2008) mentioned that natural compounds from spices extract, for example cinnamon, thyme, rosemary and oregano showed antimicrobial activity. Combination of paper packaging with several herbs and spices components have been done in the past, for example, the combination of paper packaging with oleoresin extracted from ginger (Wiasuti et al., 2016), oleoresin extracted from cinnamon (Kusuma, 2016) and also oleoresin extracted from curcuma/ *Curcuma xanthorrhiza* Roxb. (Atmaka et al., 2016).

Curcuma (*Curcuma xanthorrhiza* Roxb.) contains starch, curcuminoid and essential oil (3-12%). Hydroxyl phenolate in its curcuminoid produces its antibacterial activity. *Curcuma xanthorrhiza* essential oil usually contains xanthorrhizol; besides, it usually contains ar-turmerone which has insect repellent activity (Adipratama, 2009). Xanthorrhizol isolated from the ethanol extract of *Curcuma xanthorrhiza* Roxb. reported have antibacterial activity against foodborne pathogens such as *Bacillus cereus*, *Clostridium perfringens*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella typhimurium* and *Vibrio parahaemolyticus* (Lee et al., 2008). Diastuti et al. (2019) also mentioned that acetone extract and chloroform fraction of *C. xanthorrhiza* shown antifungal activities against *A. fumigatus*, *Epidermophyton sp*, *Penicillium sp* and *T. rubrum*.

Curcuma is commonly used as herbal drink material by pressing and separating the aqueous and solid parts. Only the aqueous part of curcuma is then processed into curcuma drink, while the solid part is usually thrown away as waste. However, the solid waste of curcuma still contains curcumin (0.031–0.044%) and essential oils (0.12–0.15%), which have antimicrobial and antioxidant properties (Wibowo, 2003). Because of that, Atmaka et al. (2016) enriched active paper with oleoresin extracted from the solid waste curcuma and reported that the 4% oleoresin was needed to increase the inhibition zone of *Aspergillus niger* growth. Another study also showed that 1.25-2.5% of eugenol from clove on hydrophobic starch solution could inhibit the growth of pathogenic bacteria, including *Escherichia coli*, *Bacillus cereus* and *Staphylococcus aureus* (Vanit et al., 2010). Meanwhile, the use of active packaging incorporated with cinnamon essential oil could inhibit the browning of mushrooms (Echegoyen and Nerín, 2015). However, the use of active

paper packaging enriched with oleoresin from pressed curcuma waste on strawberry has never been studied before.

Commonly, strawberries are packed on the punnet with paper placed on the bottom part. Echegoyen and Nerín (2015) mentioned that a larger surface area of active paper that has contact with the fruits could increase the antimicrobial properties. Hence, the purpose of this study was to investigate the effect of active paper packaging placement methods on strawberry quality, including its physical, chemical and microbial qualities, by measuring the weight loss, color change, hardness, pH value, total titratable acids (TTA), vitamin C content, total dissolved solids and the presence of microorganisms by using Total Plate Count (TPC) during refrigerated storage.

MATERIALS AND METHOD

Preparation of strawberries

Fresh strawberries were obtained from Andi Stroberi (strawberry farm at Tawangmangu, Karanganyar, Indonesia). Strawberries were collected in boxes and transported to the laboratory prior to the sorting and cleaning with dry tissue papers.

Preparation of active paper packaging

Active paper was prepared from 15 g of paper pulp immersed in 250 mL distilled water for 24 hours. Then, 250 mL water was added and mixed with tapioca starch (4.5 g 50 mL⁻¹ distilled water), chitosan in 1% glacial acetic acid (0.45 g 100 mL⁻¹) and 4% (w/w of paper pulp) oleoresin extracted from the solid waste of pressed *Curcuma xanthorrhiza* Roxb. (Atmaka et al., 2016). The ingredients were mixed, molded and dried to form active paper (Manuhara et al., 2016).

Application of active paper packaging

The covers of the mica PET punnets were perforated with 4 holes of 0.6 cm diameter spaced 1.5 cm apart (Echegoyen and Nerín, 2015). The active papers (213±1 cm²) were placed in the mica PET punnets with various methods. Mica without active paper packaging (A) was used as the control and active paper was evaluated with four different placements: on the bottom (B), on the bottom and walls (C), covering all surfaces (D) and cut into pieces then placed on the sidelines of strawberries (E). Three active papers (7 cm x 10.2 cm) were prepared for B samples and

placed on the bottom of mica PET punnets. For C treatment, two pieces of 9.5 cm x 6.5 cm active paper were placed on the bottom side while two pieces of 9.5 cm x 2.8 cm and two pieces of 6.5 cm x 2.8 cm active paper were placed on three walls side of punnets. Six pieces of active paper covered all punnet by placing 9.5 cm x 6.5 cm on the top and bottom, 9.5 cm x 2.8 cm or 6.5 cm x 2.8 cm on all part of walls to prepare D samples. The active papers (213 cm²) were cut into little pieces of 2 mm x 20 mm size and placed between the strawberries for E treatment samples. Strawberries (7 pieces) were placed in each punnets and stored for 12 days at 10 ± 2°C. They were analyzed on day 0, 3, 6, 9 and 12 to evaluate the quality of strawberries.

Physical analysis

Physical analyses were performed to evaluate changes in strawberry quality in terms of weight loss, hardness and skin color. Weight loss was analyzed by using gravimetric method (Nasution et al., 2012). Skin color was analyzed using a PCE-RGB (red, green, blue) color analyzer (Lutron Electronic) with a white calibration value of 1,023 for all three indicators. Hardness was analyzed with a FR-5105 fruit hardness tester (Lutron Electronic).

Chemical analysis

Chemical analyses were performed to evaluate changes in strawberry quality including vitamin C content, pH value, TTA and total soluble solids. A Checker pH Tester-H198103 (Hanna Instruments) was used to measure the pH after sample homogenization in an equal amount of distilled water (AOAC, 1995). Total soluble solid was measured by using an ATAGO hand refractometer. Vitamin C content was analyzed by iodometric titration (Sudarmadji, 2010). TTA was analyzed by titration method, using phenolphthalein as an indicator and 0.1 N of NaOH as a titrant (Sudarmadji, 2010).

Microbiological analysis

Microbiological analysis was performed to evaluate changes in strawberry quality by the TPC test. Nogales-Delgado et al. (2013) mentioned that due to Regulation E.C. (No. 2073/2005), the end of the shelf-life from the microbiological point of view, set at 6 log colony-forming units (CFU) g⁻¹ for total aerobic count mesophiles or TPC values. TPC values were determined by analyzing 10 g samples of aseptically minced strawberries,

which were homogenized in 90 mL of sterilized 0.85% NaCl saline water. After serial dilution in the same saline solution (9 mL), 1 mL of each diluted sample was plated on plate count agar (PCA; Merck) in duplicate. The inoculated plates were incubated at 37°C for 2 days. TPC was expressed as log₁₀ CFU g⁻¹ (Fardiaz, 1993).

Statistical analysis

The research was designed to evaluate the effect of active papers placement method on strawberries quality by packaged strawberries at different treatments (A-E) and each experiment was replicated twice. Data were subjected to

one-way analysis of variance at a significance level of $p < 0.05$ and differences in the mean values were determined by Duncan's test, using SPSS Statistics 16 software.

RESULTS AND DISCUSSION

Physical analysis

A fresh strawberry should be firm to touch and bright red. This condition can be analyzed by evaluating the changes in weight loss, firmness and color of strawberry. Weight loss was induced by water loss, followed by the softens of fruit flesh and color degradation.

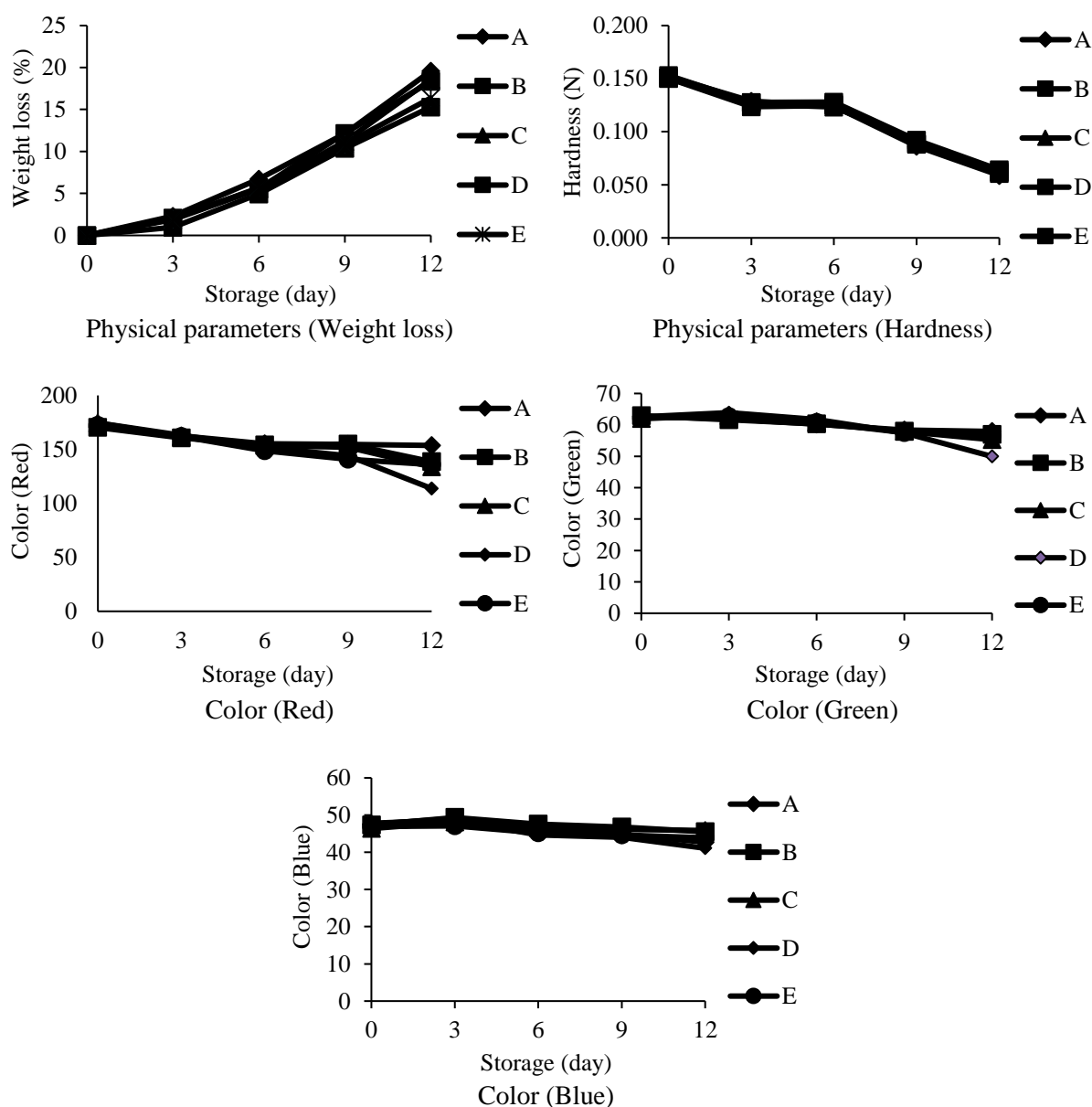


Figure 1. Effect of active paper packaging containing oleoresin extracted from the solid waste of pressed *Curcuma xanthorrhiza* Roxb. placement methods on the physical properties of strawberries during refrigerated storage

Weight loss

Weight loss increased significantly ($p < 0.05$) in all treatments with prolonged storage (Figure 1). Weight loss during fruit storage is due to transpiration, which releases water from the fruit and respiration, which involves the degradation of organic components (carbohydrates, fats and proteins) to produce energy. This results in the release of water and CO_2 is the reduction of weight of the fruit (Novita et al., 2012).

Compared to control, active paper treatments (B–E) significantly reduced the weight loss of the strawberries until the 6th day of storage. According to Echegoyen and Nerín (2015), the use of a larger surface area in active paper applications may decrease oxygen levels where the perforations are covered and increase exposure to essential oils. On the 9th and 12th days of storage, no significant differences were noted in weight loss values between strawberries in the control group and those maintained in active paper packaging. This may have resulted from the weakening of the active paper barrier during storage. The low barrier properties of paper make it not suitable for cold storage (Opara and Mditshwa, 2013).

Hardness

Fruit hardness decreased significantly ($p < 0.05$) during storage in all treatments. Softening of strawberries is caused by the loss of cell wall materials, as well as the presence of polygalacturonase, which solubilizes and degrades cell wall polyuronides (Ali et al., 2011). Deterioration of the cell wall structure in fruits can also result from the enzymatic hydrolysis of pectin and the polysaccharide matrix (Espitia et al., 2012).

Active paper packaging had no significant effect on strawberry fruit hardness (Figure 1). According to Nasution et al. (2012), fruit hardness depends on the physical condition of the fruit, i.e., wilting, wrinkles, or soft rot, which lower fruit hardness values. Wilting and wrinkles are caused by the loss of water. Nasution et al. (2012) reported that reduced water content decreases turgor pressure, which decreases the hardness of the fruit. Soft rotting on strawberries is caused by microbes such as *E. carotovora*, *P. marginalis*, bacteria from *Weeksella* genus (Yuliasari et al., 2015), *R. stolonifer* and *M. piriformis* (Siefkes-Boer et al., 2009).

Color

The color of strawberries did not significantly decrease during storage in all treatments (Figure 1). According to Nadim et al. (2015), with longer storage, the fruit becomes redder and darker. The main pigment that determines the color of strawberries is anthocyanin (Geransayeh et al., 2015), which can be damaged by heat. Light also plays a role in the anthocyanin-degradation rate; therefore, strawberries must be stored in the dark at a cold temperature (Samber et al., 2013). Significant decreases in red color were not observed after proper storage of the strawberries at $10 \pm 2^\circ\text{C}$ in the dark.

Chemical analysis

Strawberry is one of acidic fruits that contain various organic acids so the changes in chemical content such as vitamin C, pH, TTA during storage need to be investigated. Besides, TSS is related with fruit maturity and respiration rate.

pH, TTA and total soluble solids

Figure 2 shows the change of pH and TTA content, respectively, of strawberries stored with each treatment. The results showed that pH values significantly increased and TTA significantly decreased (both $p < 0.05$) during storage with all treatments; different treatments, however, did not display significantly different changes in pH or total acids at the end of storage period. Organic acids are used as an energy source for respiration and therefore, their levels tend to decrease with prolonged storage (Syafutri et al., 1970). Changes in the TTA content can also be influenced by fruit ripening; young fruits are high in acids, which levels decrease during ripening and rise again once the fruit is overripe (Novianty, 2008). The decreased total acid content increases the pH value. Figure 2 also shows the changes in total soluble solids in the strawberries during storage. Soluble solid contents decreased significantly ($p < 0.05$) with all treatments during storage. This is also due to the fruit respiration process, as sugars are used as substrates (Johansyah et al., 2014). Novita et al. (2012) also noted that fruit respiration converts sugar to pyruvic acid, producing CO_2 and water. Different treatments did not have significant effects on the total soluble solids detected at the end of the storage. Taken together, the results indicated that there were no significant differences in pH, TTA and total soluble solids at the end of storage between

strawberries in the control group and those subjected to active paper packaging, possibly due

to weakening of the active paper barrier during storage.

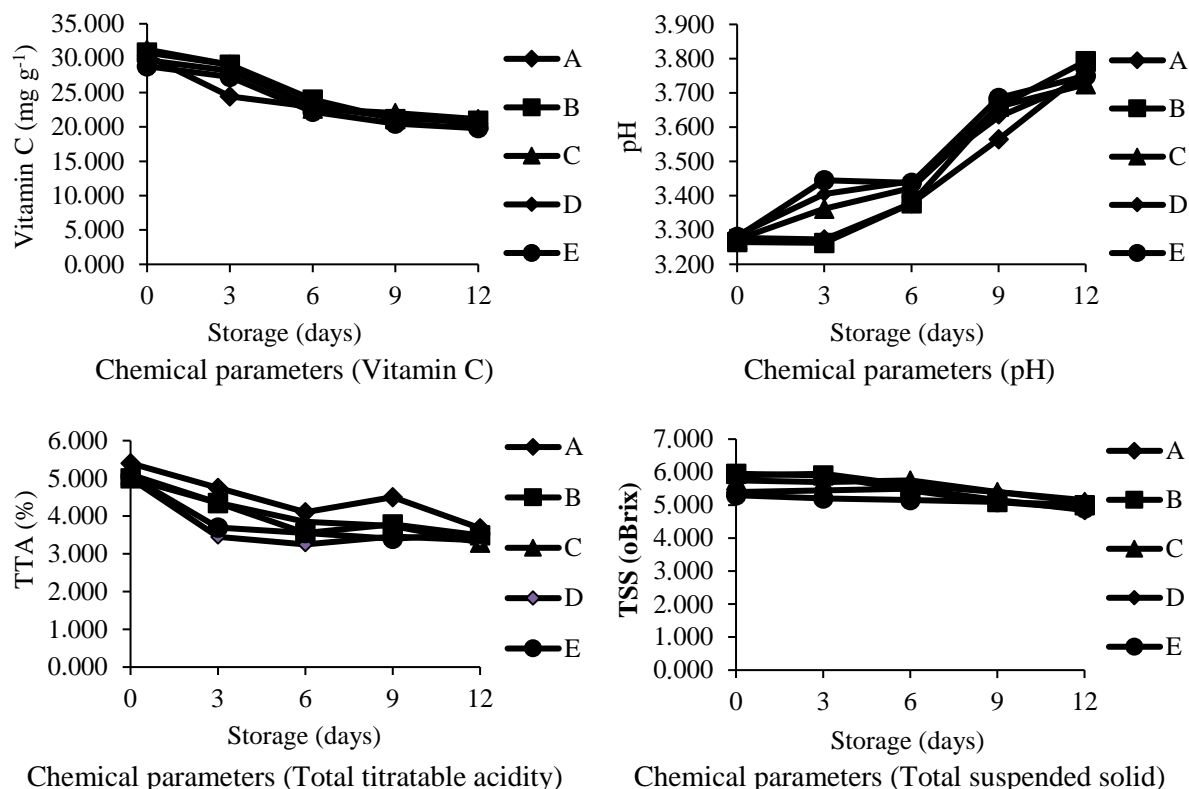


Figure 2. Effect of active paper packaging containing oleoresin extracted from the solid waste of pressed *Curcuma xanthorrhiza* Roxb. placement methods on the chemical properties of strawberries during refrigerated storage

Vitamin C

Vitamin C levels decreased during storage in all treatments, due to oxidation (Winarno, 2008) and at the end of storage, there were no significant differences among the treatment variations (Figure 2). However, control strawberries displayed a greater decrease in vitamin C content than strawberries with active paper packaging (Figure 2).

Microbial analysis

During storage, strawberries are susceptible to microbial damage which is caused by mold and bacteria. Due to Regulation E.C. (No. 2073/2005), the end of the shelf-life from the microbiological point of view, is set at 6 log CFU g⁻¹ for total aerobic count mesophiles or TPC values (Nogales-Delgado et al., 2013).

Figure 3 showed that the total microbial content on the strawberries increased significantly ($p < 0.05$) during storage for all treatments. The initial TPC values were 3.294–3.648 log₁₀ CFU mL⁻¹. At the end of storage (day 12),

the TPC values for treatments A (control) and B (bottom) were higher than the maximum acceptable limit of 6 log₁₀ CFU g⁻¹ (Nogales-Delgado et al., 2013). However, the TPC values for treatments C (bottom and wall), D (envelope) and E (cut into pieces) remained below this limit. These results indicated that a larger surface area of active paper in contact with the strawberries provided better protection against microbes. Echegoyen and Nerín (2015) suggested that the use of the larger surface area in active paper applications decreases oxygen availability and increases exposure to essential oils.

The ability of the active paper packaging to inhibit microbiological growth is attributed to the presence of curcuma compound (curcumin and xanthorrhizol) and chitosan (Atmaka et al., 2016). Curcumin is a phenol-derived compound (Setyowati and Suryani, 2013) and xanthorrhizol contains phenolic groups on a bisabolene skeleton (Jantan et al., 2012). The antimicrobial mode of action of phenol compounds is by hydrogen

bonding with cell membrane proteins, disrupting membrane permeability and causing cell death (Dermawaty, 2015). Damaged cell membranes also cause important components such as proteins

and nucleic acids to leak out of the cell, resulting in growth inhibition (Atmaka et al., 2016). Chitosan is a positive polycation that can inhibit molds and bacteria (Pebriani et al., 2012).

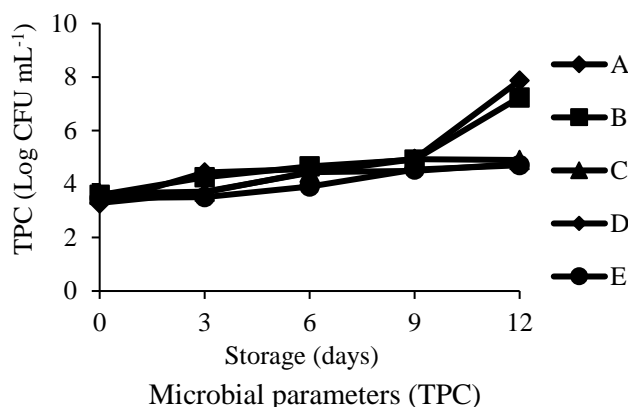


Figure 3. Effect of active paper packaging containing oleoresin extracted from the solid waste of pressed *Curcuma xanthorrhiza* Roxb. placement methods on the microbiological properties of strawberries during refrigerated storage

CONCLUSIONS

The results indicated that different placement methods of active paper had no significant effect on the physical and chemical qualities, but they did affect the microbiological quality of strawberries. After 12 days, the TPC values of control and B samples were higher than the maximum acceptable limit; while the others remained below the limit. These indicated that larger surface area of active paper that had contact with the strawberries provided better protection against spoilage by microbes. Due to microbial properties, C, D and E treatments maintained the strawberry quality for up to 12 days, compared with 9 days by control and B treatments.

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